Judging Hazard from Native Trees in California Recreational Areas:

--a Guide for Professional Foresters

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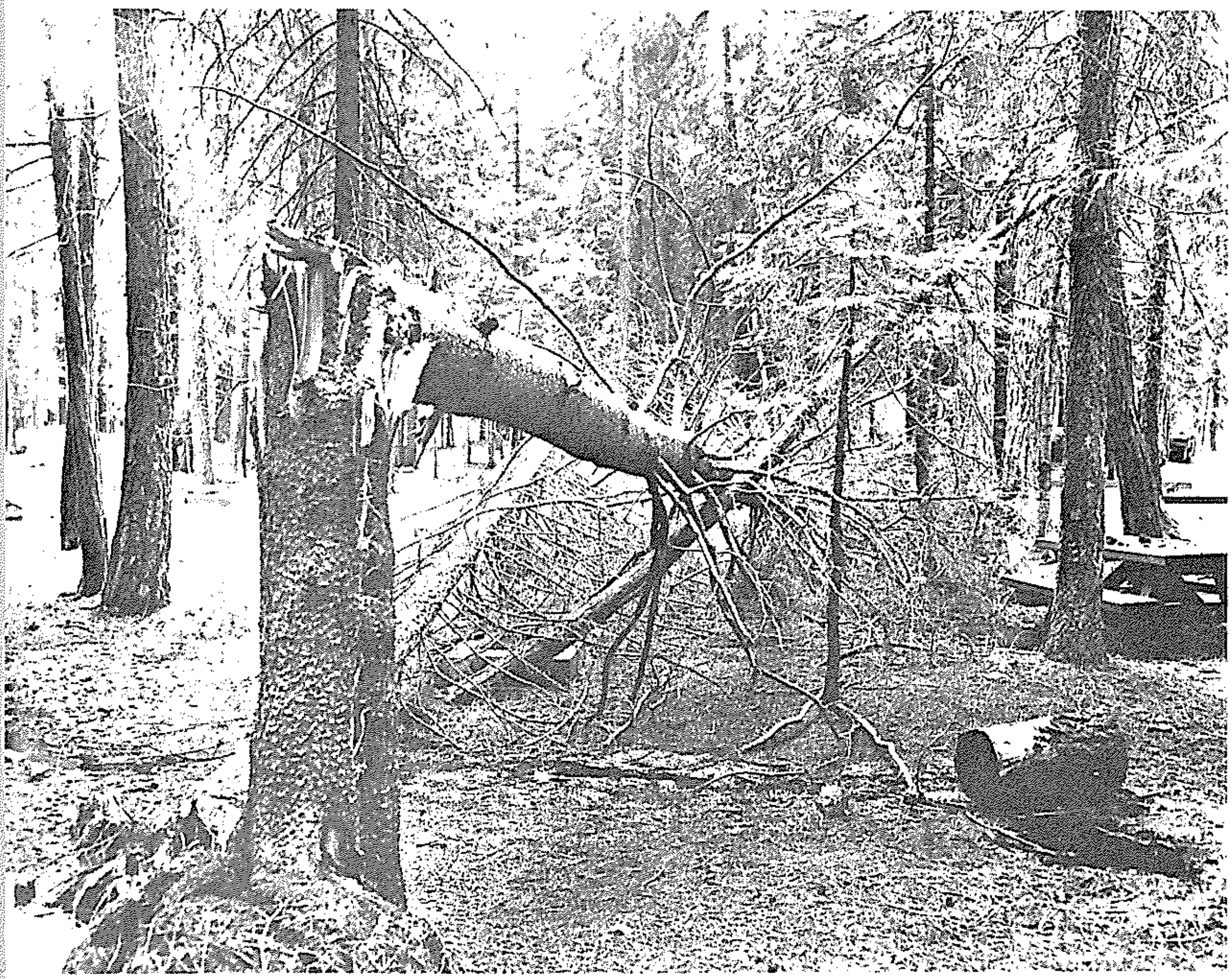

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Trees can beautify, protect, and cast a cooling shade. But they can also maim or kill if they or their parts break and fall. Failure is not likely if trees are sound, except under extraordinarily unfavorable weather conditions. Over a long life span, however, trees may suffer weakening defects that may make them unsafe. This is the potential that is of increasing concern to those in charge of forest and park recreational areas, to which people are flocking in ever-increasing numbers in California.

Defects that accompany decadence and death in trees form a part of the natural process of renewal in the virgin forest. As such, under virgin conditions, they are beneficial. But defects that seriously weaken trees in such areas take on a different significance when man enters the forests and congregates in persistent numbers at campgrounds or resort centers. They become hazards that can turn a visit or a vacation into a tragedy.

The desirability of abating tree hazards in heavily-used recreational centers is now generally recognized. But until recently, no specific information has been available on what defects are likely to render a tree unsafe or how to recognize potentially hazardous trees. This publication is a first attempt, from the best knowledge now available, at providing such information for California recreational sites. It should apply also to the reduction of tree hazards along highways and in the vicinity of homes or other structures in the woods.

This guide is intended chiefly for professional foresters charged with making safety inspections of trees in recreational areas. We assume that such men have a general background understanding of the more common tree defects that may affect safety and of the causes of defects. We further assume that they realize that any decision made regarding hazard removal is likely to have multiple effects. Some of these effects may be undesirable when measured against the intended function of the area.

The removal of a defective tree, for example, may create an opening that allows greater wind action with the increased possibility of wind damage to the remaining trees. Excessive tree removal may reduce the attractiveness of a campground to the public, thereby impairing its usefulness. It is important, therefore, that a person conducting a hazard examination should be aware of all consequences of any contemplated action. His judgment on individual trees should be based on as broad and complete a background as possible.

The Problem of Hazard

Weather

Storm Conditions

Most tree failures are associated with wind, snow, or ice, and involve some type of weakening defect. But *storm conditions may occasionally be so extreme that any forested area can temporarily be rendered unsafe by falling tops, branches, or entire trees, even if not defective.* Completely sound trees have been snapped off or uprooted during such exceptionally severe storms.

The safety of forest occupants under these conditions is assured only if they take adequate shelter or move to open ground. Lightning offers another so far uncontrollable danger in forested areas, with instantaneous hazards from electrocution or from parts flying off shattered trees.

But not all tree failures occur during windy or stormy weather. Defective trees sometimes topple when the air is still (fig. 1). These failures are more dangerous than those occurring during storms because they are likely to take place when recreational use is heavy. Thus detection of trees that can fail in the absence of wind is especially important.

In many areas, nature helps reduce hazards in

Figure 1.—This massive oak toppled at 6:10 a.m. on a windless July morning. The tree had been weakened by butt and root rot, principally from the honey fungus.

the forest by breaking down weak trees or branches during winter storms when the areas are not likely to be occupied. This is particularly true in localities subject to heavy wet snows. Thus the actual safety status for a particular location depends in part on its climatic conditions and in part on its occupancy pattern.

Safety standards need to be more strict under year-round occupancy than for occupancy only from May through September. Similarly, stricter standards are necessary for trees near valuable structures than for those away from such developments. Low elevation coastal parks and campgrounds, where snowfall is rare, can be quite different in hazard potential from those in mountain areas where snow and ice loads on trees are common annual occurrences.

Wind

Wind, acting either alone or in combination with snow or ice, causes most tree failures. In any one location the heaviest winds can be expected to come from not more than two general directions. These directions will vary somewhat, depending on the part of California involved and on the topography, but one direction is usually southerly, blowing in advance of storm centers moving down from the northwest. Severe southerly winds blow almost exclusively during late fall and winter. The other main direction for high winds is from the north to the east, depending on topography, in response to a steep air pressure gradient from the interior plateau regions of eastern California toward the coast.

Direction Orientation

With some types of defects or abnormalities, orientation as to wind directions strongly influences the likelihood of failures. The case of a ponderosa pine tree in a recreational area provides an example. Years ago, when the tree was much smaller, a wooden crossarm was spiked to the westerly side of the trunk at a height of about 15 feet. Subsequent thrifty growth of the tree caused the trunk to become flattened at that point and the crossarm to become slightly embedded. During a very severe and gusty autumn east wind the trunk broke at this point, although the wood was sound, and fell across a cabin. Failure of a tree with that much sound wood is unusual, even when the tree has a flat side. But at that location some of the strongest winds sweep in from the east and northeast. If the crossarm had been spiked in a direction parallel to these winds, such as to the south or northwest sides of the tree, the break probably would not have occurred.

The same principle applies to dead areas in mistletoe swellings, crotches of forked trees, or large open fire wounds associated with internal decay. Failure is more likely when the dead faces are toward or opposite the direction of heavy winds, or when crotches are at right angles to rather than parallel to the direction of these winds.

Orientation is likewise important when wooded parts of recreational areas adjoin large, unobstructed openings, such as provided by a meadow, lake, or cleared area. When these openings lie in a direction from which severe winds are known to blow, the border trees adjoining the openings can be expected to be subjected to unusually strong wind pressures. Defects that would not be likely to render a tree hazardous under normal stand conditions might make it unsafe in these strongly exposed situations.

Wood Strength

Liability to breakage in a tree depends in part on the mechanical strength of the wood. This strength differs in different tree species. In a standing tree, wood must resist bending and crushing under a load applied parallel to the grain. Wind pressure against a tree exerts a compressive force on the wood of the trunk on the lee side of the tree and a tension pull on that of the opposite side. The compressive wind force is in addition to that from the normal weight of the tree and sometimes, in winter, from the weight of snow or ice that may lie on the crown.

Standard Tests

Various standard tests have been developed for comparing the mechanical strength and properties of both green and dry wood. Among these are the modulus of rupture test and the test for maximum crushing strength parallel to the grain. They are the most applicable in comparing the strengths of standing trees. The modulus of rupture test gives an index to the bending strength. Table 1 compares the average modulus of rupture and maximum crushing strengths of green sound wood for a number of tree species in California. It shows that strengths differ considerably among the species. The wood of Douglas-fir, redwood, tanoak, Garry oak, and Pacific madrone is measurably stronger than that of other California species included in the table and should be less likely than the others to fail under a given stress.

In considering forest hazards, however, we are more concerned over the loss in strength of wood from rot, usually internal, than over the comparative strengths of sound trees. In advanced cases, some heart rots may cause the heartwood to collapse, leaving a central hollow in a tree; or the decayed portion may not collapse but no longer provides any appreciable mechanical support to the affected parts of the trunk.

The Forest Products Laboratory of the U. S. Forest Service has found that both bending and compressive strengths affected the strength of a solid wood cylinder, but at different ratios (fig. 2). Application to a live hollow tree can be only approximate, because the thickness of the wall of sound wood around a hollow from decay is seldom uniform, either horizontally or vertically. Both bending and compressive strengths contribute to the resistance of a hollow tree to failure. The combined weakening effect of a hollow or of a rot column that no longer provides any appreciable mechanical support is roughly similar to the cubes of the diameters of the wood of the trunk and that of the hollow at the height of reference (fig. 3).

Expressed simply, a hollow tube represents a relatively high degree of strength as compared to that of a solid cylinder—a relationship often used in fabrication and construction in which weight is a factor. Thus a tree trunk with a hollow measuring half the total wood diameter is reduced in

Table 1.--Average modulus of rupture and average maximum crushing strength parallel to the grain of green wood of some California conifer and hardwood species

Species	Modulus of rupture[1]	Maximum crushing strength parallel to the grain[1]
	P.s.i.	P.s.i.
Conifers:		
Douglas-fir (coast form)	7,600	3,800
Redwood	7,500	4,200
California red fir	6,000	2,850
White fir	5,700	2,710
Lodgepole pine	5,500	2,610
Sugar pine	5,100	2,530
Ponderosa pine	5,000	2,400
Hardwoods:		
Tanoak	10,700	4,850
Garry oak	7,700	3,570
Pacific madrone	7,600	3,320
Bigleaf maple	7,400	3,240
Red alder	6,500	2,960
California black oak	6,200	2,800
Black cottonwood	4,800	2,160

[1] Data from U.S. Forest Products Laboratory, chiefly from Wood Handbook, U.S. Dept. Agr. Handb. 72, 528 pp., 1955, and in part from unpublished test results.

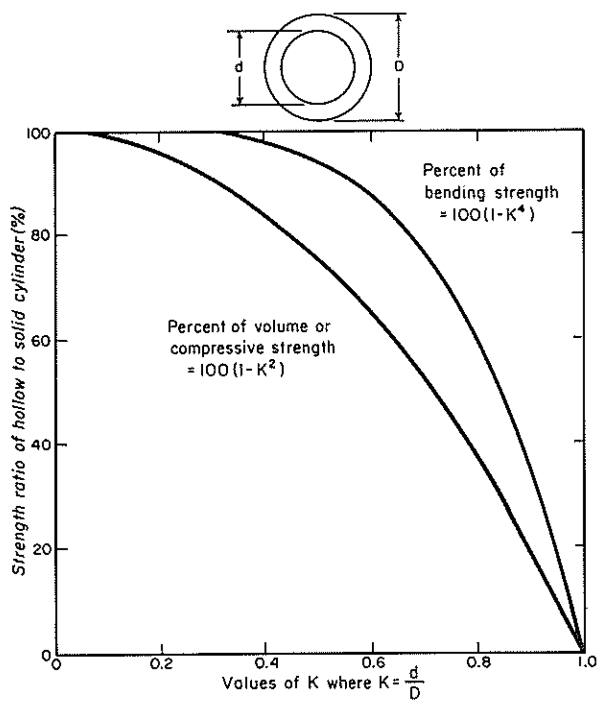

Figure 2.—Strength values in a hollow compared to a solid structural wood member of circular cross section. Compressive strength decreases as the square, and bending strength as the fourth power of the difference between the outer diameter and the diameter of the inner hollow in the wood member.

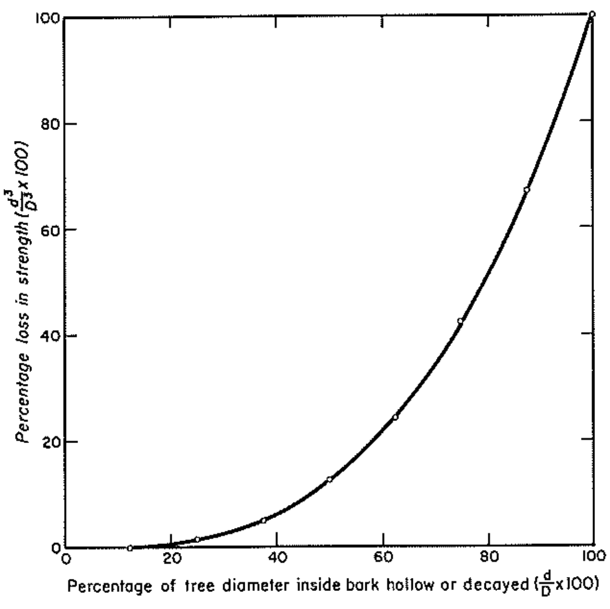

Figure 3.—Approximate percentage loss in strength in tree trunks with advanced center heart rot, or hollow from heart rot, compared with the strength of sound trees.

strength by only about 12.5 percent (fig. 4), if the hollow is centered and the width of the surrounding wall of wood is uniform. The application of the formula of cubed diameters to individual trees is described elsewhere.

Under side stress, a tree resembles a cantilever in that anchorage lies at the bottom only. In conifers and to a lesser extent in hardwoods the form of the trunk is such that resistance to side strain is distributed more or less uniformly along it. But observational and test evidence indicates that most failures of sound conifers, other than failures from snowbreak in the absence of wind, occur in the lower trunk. In defective trees, the zone of greatest weakness created by the defect usually determines the place of failure.

Breakage Source

Sound trunks or trunks with a complete ring of sound wood around the periphery break chiefly

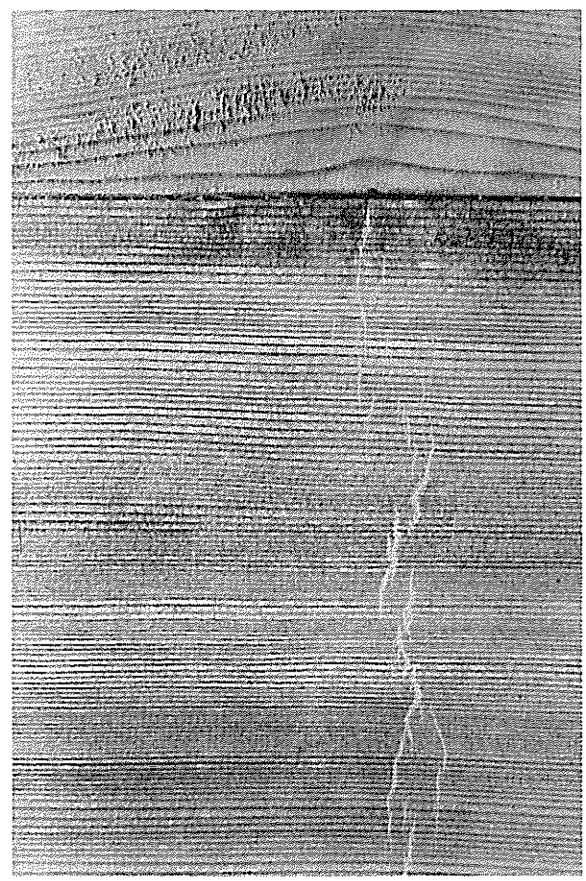

Figure 4.—Compression failure in wood. The whitish lines consist of crushed wood cells resulting from excessive pressure parallel to the grain.

from compression defects formed in the wood on the lee side of the tree during heavy winds. These defects consist of zones of crushed wood cells (fig. 4), usually extending diagonally across grain from the outside of the trunk toward the center on the side of the tree subjected to the compression force. A trunk may not actually break at the time the compression defect is created. One case is reported in which compression damage occurred in a tree trunk on three occasions over a period of 13 years. But an actual break did not develop until the fourteenth year, from a lighter wind than those producing the compression defects, but in the opposite direction.

Time and Tree Type Differences

Time Factor

Some defects in forest trees are produced almost instantaneously and render the tree potentially hazardous as soon as they occur. An example is a split through the crotch of a fork in a forked tree. But with most defects that may ultimately render a tree hazardous, the transition from a safe to a potentially unsafe condition is a very gradual one, and no sharp line of demarcation exists between the two.

Decays do not spread at any one speed in the trunk and the wood does not break down into advanced rot at a uniform rate. The rate differs not only for different decay fungi but for different climatic conditions, different host species, and different individual trees within the species. The occurrence of geographical races of the same fungus has also been demonstrated. These races differ in their rate of development at the same temperatures. In general, the rate of advance of a rot fungus in a tree is slow, requiring many years for the resulting rot to become extensive.

Because of these many differences, attempts to predict the rate of decay, such as to judge that within 10 years a tree not considered hazardous now will be weakened enough to become hazardous, are likely to be so inaccurate as to be useless. An inspector should base his judgment of a tree on its present condition, not on what he thinks the condition will be X years from now.

Hardwoods v. Conifers

In general, hardwoods undergo more stresses than conifers because of the differences in form between the two groups. Most hardwoods have a spreading habit that results in a rounded crown. Most of them are strongly influenced by light, leading to pronounced lopsidedness in crowns where the surroundings are not fully open. More strength is needed to resist storm effects by trees with spreading and irregular crowns of this sort than by conifers with crowns arranged around a central trunk. This is particularly true when the crown is weighted by snow or ice. The relatively high mechanical strength of most hardwoods (table 1) compensates in part for the need.

Heart rots in hardwood trunks commonly extend into the main branches, whereas in conifers such extension is much less frequent. This characteristic in hardwoods, together with the difference from conifers in crown shape, results in most hardwood failures taking place in branches or in crotches where branches join the main trunk, rather than in the trunks themselves (if butt failures are left out of consideration). Hardwoods are much more prone than conifers to damage in the crowns from snow and ice. Basically this means that leverage is one of the most important elements affecting the safety of hardwoods. The effect of leverage is likely to vary from limb to limb and tree to tree.

Rots and Hazard

The single most important process contributing to hazards in the forest is the destruction of wood by wood-rotting fungi. Many such fungi are found in California, but only a relatively few are of primary importance in affecting the safety of trees. No attempt has been made in this paper to provide pictures of individual rots because the specific characteristics are not likely to be too obvious in the woods. By the time a heart rot has reached a stage of materially affecting the strength of the trunk, the breakdown in the wood has often proceeded so far that much of the individual character of the rot has been lost. Within large open wounds, secondary or successional fungi often invade and tend to obliterate some of the distinguishing characteristics of the primary rot. For these reasons the decays as actually seen in advanced cases in defective trees may not closely resemble the pictures of the respective rots shown in textbooks. But most rots fall into two general types that are readily distinguishable from each other: (a) white rots and (b) brown rots. The ability to recognize these types is helpful in diagnosis.

Types and Classes of Rot

Type Differences

The two types of rot arise from differences in the nature of the decay process in each. In white rots, which may actually range in color from whitish to reddish or brown, all wood constituents are attacked, resulting in soft and flaky or stringy decay (fig. 5). Brown rots, on the other hand, are caused by fungi that remove the cellulose of the wood but leave the lignin. The resulting rot may be from light to very dark brown. Friable in texture, it reduces to a powder when rolled between the fingers, and breaks up from shrinkage cracks into rectangular chunks (fig. 6). This type of decay is sometimes popularly known as "dry rot," although the affected wood is actually quite moist during the decaying process.

Growth Environment Differences

Rots also divide roughly into two classes, not readily separable visually, based on different activity potentials in trees and thus differing in their capacity to render a tree hazardous.

The first class is from fungi adapted to growth in dead branches or exposed sapwood: locations where the oxygen supply is ample. They are essentially saprophytes and are more common on hardwood trees than on conifers. Most of them can extend from a decaying branch into the heartwood of a larger live branch or trunk to which the decaying branch is attached, but they seldom progress far in the live member. If the opening through which the fungus extended is later healed over, cutting off the oxygen supply from the outside, the decay process is restricted and eventually the causal fungus may die. Fungi of this class seldom result in extensive decay within the tree unless the trunk has numerous openings.

The other class arises from the true heart-rot fungi which are adapted to growth in a limited oxygen supply if necessary. They can progress in

Figure 5.—A typical white rot from the yellow cap fungus in the heartwood of California red fir.

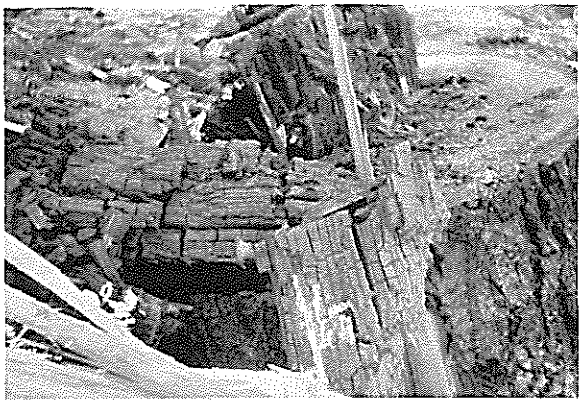

Figure 6.—A typical brown cubical rot from the sulfur fungus in the heartwood of California red fir.

heartwood for indefinite distances, regardless of openings. Most cases of extensive heart rot in trees develop from these true heart-rot fungi.

No easy way is known for distinguishing between these two classes of rot fungi in the field. In general, the first class is made up of fungi that rot dead limbs and exposed saywood; the second class consists of fungi that develop only in heartwood. But a few fungi are in an intermediate class. For the person in the woods, the important thing is to understand that these two general classes exist and that a rotten limb often does not indicate extensive internal rot.

Most heart rots tend to develop in a particular part of a tree, such as the trunk or butt. These differences in location often arise from differences in the common places of entry of the causal fungus: fungi that normally enter through branch stubs on the trunk develop as trunk rots; those that enter through basal wounds, such as fire wounds, develop as butt rots or rots of the lower trunk. This does not mean that trunk rots do not occasionally extend down into the butts of trees or vice-versa but that, in general, they center in the particular part of the tree where establishment first occurred. The location within the tree thus becomes a convenient basis for reference to the important decays that may influence tree safety.

Trunk Rots in Conifers

Only a few trunk rots are likely to influence the safety of coniferous trees in recreational areas in California, although a number of others may occasionally do so. None of the trunk rots is as important in rendering trees potentially dangerous as root and butt rots.

Hosts listed below are for California only and only for tree species that may be found on recreational areas.

Brown Stringy Rot

Hosts.—White and California red firs.

Causal fungus.—Indian paint fungus *Echinodontium tinctorium.*

Indicators.—Perennial conks (one to six or more) on trunk, issuing under dead branch stubs or at knots (fig. 7).

Conks.—Rough and blackish on top; grayish and toothed or spiny underneath; a light brick or rusty red interior; 3 to 12 inches wide.

Place of infection.—Chiefly through knots and branch stubs.

Rot.—Late stages stringy; rusty brown, although basically classed as white rot.

Figure 7.—Conks of the Indian paint fungus on a white fir trunk. (National Park Service photo.)

This rot causes occasional failures in old firs, almost exclusively during severe winter storms. The size and distribution of the conks gives a rough index of the stage and extent of the rot within the tree. Conks less than half a foot across are ordinarily young and indicate that the rot at that point has probably not yet reached an advanced stringy stage unless the affected tree is small and suppressed. Larger conks indicate that the fungus has long been established in the tree and that the rot is in the late stringy stage, extending for many feet above and below the conk. Extensive decay is also indicated by conks widely spaced along the same trunk, such as more than 10-feet separation in vertical distance between upper and lower conks.

The decay is restricted to the heartwood and in some instances may not affect the entire cross section of the heartwood column. The degree of weakening depends much upon the width of the saywood, which in turn is governed chiefly by the rate of diameter growth of the tree.

Mottled Rot

Hosts.—White and California red firs. (Also occurs on several hardwood species but not common on these in California.)

Causal fungus.—Yellow cap fungus *Pholiota adiposa.*

Indicators.—Annual conks.

Conks.—Mushroomlike, yellow, with gills on the under surface; soft, short-lived; appears in clusters through bark crevices or at edges of open wounds after fall rains.

Place of infection. — Chiefly through open wounds or dead areas, such as fire wounds and the exposed wood of dwarfmistletoe cankers.

Rot.—Late stages whitish, mottled with brown; narrow, irregular channels or pits in the decayed parts.

Mottled rot that has become established through open basal fire wounds (fig. 5) may extend up in affected trunks for as much as 50 to 60 feet. That developing in the dead parts of open dwarfmistletoe cankers is usually localized in the cankered part of the trunk swelling. Except for locations where exposed dead sapwood is present, the decay is confined to the heartwood. In old infections the rot may collapse, leaving a hollow butt.

The weakening effect on a tree trunk thus depends on the thickness of the zone of live sapwood outside the decayed heartwood and the relation of this width to the total radius of the trunk at the level of maximum rot development.

Brown Cubical Rot

Hosts.—California red fir and hardwoods, such as oaks and eucalyptus.

Causal fungus.—The sulfur fungus *Polyporus sulphureus.*

Indicators.—Conks appearing from openings in the trunk, usually near the tree base. The conks are annual in that they last for only one season, but do not develop every year.

Conks.—Clusters of thin, shelf-like fruiting structures, soft when fresh, bright orange on top and bright sulfur-yellow underneath; becomes hard and brittle upon aging, changing to a chalky or grayish white. Broken remnants of this stage may persist on the trunk for some months. Size variable, but usually 8 inches or more wide.

Place of infection.—Chiefly through open trunk wounds or dead branch stubs.

Rot.—A brown cubical heart rot, usually centering near the base of affected trees (fig. 6).

*Failures of California red firs from brown cubi*cal rot appear to be relatively rare. When they do occur, the failures are usually during severe winter storms. The cubical rot in large open basal wounds, such as those from fire, often indicates the presence of decay in the heartwood of affected trees.

The following two trunk rots are included here because they are so common in their chief host species in California that questions may arise concerning their effect on tree safety. Both are pocket rots of the heartwood from fungi that do not invade the wood uniformly, but leave a framework between pockets that continues to provide partial support to the trunk. For this reason, failures in trunks in which these rots are present are rare, except under extreme storm conditions. Their presence should thus not be regarded as rendering a tree unsafe.

Red Ring Rot ("White Speck")

Hosts.—Chiefly Douglas-fir; occasional in sugar pine, ponderosa pine, white fir, incense-cedar, and several other conifers in California.

Causal fungus.—Ring scale fungus *Fomes pini.*

Indicators.—Perennial conks; swollen knots; sometimes by the presence of cupped bark plates in such species as ponderosa pine and white fir.

Conks.—Numerous, shelflike; scattered along affected trunks, appearing mostly at knots but in white fir directly on the bark. Hard and woody; upper surface rough dull grayish or brownish

Figure 8.—Hollowness in the stump and in a main branch of a black oak, decayed by a white-rot fungus. Note the greater degree of hollowness in the branch, as compared with that in the trunk at stump height. (National Park Service photo.)

black, concentrically furrowed, under surface brown or grayish brown, pore mouths irregular in outline. Varies from 1 to nearly 12 inches wide, mostly not more than 6 inches wide.

Place of infection.—Mostly through branch stubs or open knots.

Rot.—In advanced stage, consisting of numerous small white pockets separated by firmer wood walls; pockets either occurring uniformly across the affected wood or confined to concentric zones or bands. Decay confined mostly to heartwood, although sapwood may be affected by the fungus in the vicinity of punk knots, or adjacent to heartwood where the decay is well advanced.

Pocket Dry Rot

Host.—Incense-cedar.

Causal fungus.—*Polyporus amarus*.

Indicators.—Conks or shot-hole cups, the latter marking in the bark the location of former conks. The shot-hole cups show numerous worm holes in the bark, with part of the bark often chipped away by woodpeckers searching for larvae in the wormholes.

Conks.—Soft, fleshy, bracket or bell-shaped, tan on top and bright sulfur-yellow underneath; becomes tough and brown on aging, and eventually hard and dry; 4 to 12 inches wide. Produced only in occasional years and on only occasional infected trees.

Place of infection.—Large open wounds in which heartwood is exposed.

Rot.—Pockets of dark brown cubical rot in the heartwood, the pocket separated by essentially sound wood. Pockets variable in size and shape, mostly 6 to 12 inches long, but many shorter, mostly not over 1½ inches wide.

Trunk Rots in Hardwoods

A rather long list of decay fungi has been found in hardwoods in California, but only a few are sufficiently common or cause a decay extensive enough to warrant mention here. Because of the difference in tree form in the hardwoods as compared to conifers, most trunk rots in hardwoods also extend into the main branches, where they may cause greater weakening than in the main trunk (fig. 8).

The oaks are among the most common hardwoods within recreational areas in California and, if old, they are also among the most defective. Two of the three decays listed below are found chiefly in oaks.

White Pocket Rot ("Piped" Rot)

Hosts. — Oaks, particularly California black oak.

Causal fungus.—*Polyporus dryophilus.*

Indicators.—Conks or their remains; rot of the fungus showing through trunk or main lateral openings.

Conks. — Light brown, darkening somewhat with age, usually hoof-shaped, up to 6 inches wide; issuing at knots or open wounds. A hard gritty core persists for many weeks after the balance of the conk has eroded away.

Place of infection.—Mostly through broken branches or open wounds.

Rot.—Consisting of long, narrow white pockets in the heartwood, running together longitudinally. The rot may ultimately collapse partially, creating irregular hollows within affected heartwood. Confined to the heartwood, usually of the upper trunk and main branches.

Figures on the prevalence of specific decays in the oaks of California are not available, but dryophilus rot is undoubtedly one of the most common, particularly in mountain and foothill areas. Breakage of trunks or main branches because of its presence ocurs almost exclusively during severe windstorms or, more commonly, from the weight of clinging snow in snowstorms.

Brown Cubical Rot

This rot is described in the section on trunk rots in conifers.

In oaks, this decay is almost always confined to the lower trunk because the fungus becomes established chiefly through basal fire wounds. But it may occasionally center higher up in the trunk. The rot is confined to the heartwood, but usually involves the entire heartwood cross section. The presence of the rot is usually detectable within open basal wounds.

White Trunk Rot

Hosts.—Aspen and willow in California.

Causal fungus.—False tinder fungus *Fomes igniarius.*

Indicators. — Perennial conks on affected trunks.

Conks.—Common on affected trees; from one to many per tree, emerging at knots and branch stubs; hoof-shaped, 2 to 8 inches wide; upper surface grayish black to black, rough and cracked; under surface brown with small circular pores; interior is rusty brown, showing many layers of tubes.

Place of infection.—Branch stubs, knots, and open wounds on trunks.

Rot.—A soft whitish rot in the advanced stage, rather uniform in texture with fine black zone lines running irregularly throughout. Not collapsing or forming hollows, confined to heartwood.

This rot is quite common in aspen in California, but spotty in occurrence. It may be prevalent locally in some stands but absent in others. It rarely causes failure in affected trees, in part because the rot never collapses to form hollows within affected trunks and in part because the proportion of heartwood to sapwood is usually not as large in aspen as in mature trees of many other native tree species.

Root and Butt Rots

California has several diseases in this category that may materially affect tree safety. One of them, caused by the fungus *Armillaria mellea,* ranks among the most important sources of tree hazard.

Shoestring Root Rot

Hosts.—Among forest trees chiefly oaks and white and California red firs.

Causal fungus.—Honey fungus or oak root fungus *Armillaria mellea.*

Indicators. — Flattened black rhizomorphs ("shoestrings") over bark below ground level or between bark and wood in dead areas. Conks (fruitbodies) when present.

Conks.—Mushroomlike, appearing in clusters at the ground line around the base of infected trees after fall rains or in the spring. Color varies from honey yellow to dark smoky gray. Soft and fleshy, short-lived; under surface with radiating gills rather than pores.

Place of infection.—Through basal wounds or by way of roots.

Rot.—In the advanced stage, whitish, soft and spongy; often becoming somewhat stringy in white and California red firs; traversed by irregularly distributed black zone lines in most cases.

The causal fungus of this rot can decay physiologically dead wood, such as heartwood, and also can kill live wood. It is often associated with the roots and butts of decadent oaks. It is an important killer of planted trees and shrubs in orchards and gardens on ground formerly occupied by oaks or other susceptible native vegetation. But in California forests, although it may occasionally kill young conifers in the vicinity of affected oaks, its chief role is to cause butt and root rot in oaks and true firs. Affected trees may eventually fail at the base, either during strong winds or under perfectly calm, still conditions (fig. 1). Several accidents or near-accidents in campgrounds or similar heavily-used recreational areas have been traceable to the destruction of wood in roots and tree bases by this fungus.

In infected bark, small, thin white mycelial plaques are formed within the bark layers when the fungus is active. In hardwood bark, the mycelium of these plaques has a fan-shaped pattern, but in conifers the pattern is usually straight and parallel. Concurrent with formation of the plaques, a felt of white mycelium develops between the bark and wood at the butt of infected trees.

A unique feature of the fungus is the formation, in well established cases, of flattened blackish fungus structures known as rhizomorphs. Their appearance suggests black shoestrings, hence the common name of "shoestring fungus." They usually appear either over the outside of the bark below ground level, or form between wood and bark if patches of bark have been killed and have separated from the wood. No other native butt and root rot fungus in the West produces such structures. Accordingly, if found, they provide positive evidence of the presence of the Armillaria fungus.

The fungus destroys the basal heartwood of affected trees, but usually does not extend up in the trunk in the heartwood for more than 10 feet. A hollow is often formed in the butt from collapse of the decayed wood there. The basal sapwood near ground level may also be invaded and killed, along with the overlying bark, but not uniformly. Thus, killing of sapwood may be in progress along one part of the circumference of the tree near ground level but not along other parts. A tree often may fail at the base before it is dead, except for California live oak and Engelmann oak, in which direct killing by the fungus is not unusual. Both oaks and firs weakened at the base by the fungus may fall in the absence of wind, either in the evening or early morning hours after a moderately warm, dry day.

Annosus Root and Butt Rot

Hosts.—White and California red firs; occasional in Douglas-firs. Also attacks and kills ponderosa, Jeffrey, and other pine species, but without causing a butt rot in them as it does in the firs.

Causal fungus. — The Fomes root fungus *Fomes annosus.*

Indicators. — The relatively characteristic rot showing in open basal wounds; sometimes crown deterioration evidenced by the presence of scattered dead twigs and branches when not caused by dwarfmistletoe, and by reduced foliage growth.

Conks.—Irregular in shape; in firs developing only within the hollow butts of trees badly decayed by the fungus, often at ground level or below. Perennial, whitish to light brown when fresh, tough and corky in texture, later darkening and hardening. Shreds of old decayed wood are often incorporated into the conks.

Place of infection. — Usually through open basal wounds such as fire wounds. May also enter through roots.

Rot.—In the advanced stage in firs, white, soft, and stringy, with white pits, these sometimes showing black centers; the rot often eventually collapses in the butt, forming a hollow. Chiefly confined to the heartwood, but may extend into the roots or part of them.

In some native pines of California this fungus is an active killer, especially around stumps in which it has become established. But in the true firs and Douglas-fir the fungus does not ordinarily invade or kill the butt sapwood. It often extends into part of the roots, however, and is a source of windfall in the firs. Most windfall in firs takes place during windstorms but occasionally affected firs fall on windless nights, usually following a warm dry day.

The rot may extend up through the heartwood from basal wounds for as much as 40 or 50 feet. Conks of this fungus in firs are almost always hidden within basal hollows and are thus of little help in identifying the presence of the fungus in standing trees. The fungus takes many years to weaken the base of affected trees enough to make them possible hazards.

In inspections for hazardous trees, suspect this fungus in any hollow-butted true fir in which the hollow is large, extends well below ground level, and is associated with a white soft rot. If the crown is also decadent, with scattered old and recent dead branches, the Fomes is almost sure to be present in the main roots.

Red-Brown Butt Rot

Hosts.—Douglas-fir, California red fir, various pines.

Causal fungus.—The velvet top fungus *Polyporus schweinitzii.*

Indicators. — Conks at tree butts or from ground near the butts; brown cubical rot showing in open basal wounds.

Conks.—Shelf-like when attached to the butts of trees; roundish, with depressed centers and short central stalks when arising through the soil from roots; often multiple. Reddish brown above, greenish yellow underneath when fresh, under surface turning brown when bruised; changing to a chocolate or blackish brown in age; annual, but the conks persistent after death; not destroyed by insects.

Place of infection.—Commonly through basal wounds, especially fire wounds; sometimes through roots.

Rot.—A yellow-brown to red-brown cubical rot, breaking into large chunks; these divided at intervals by thin, crust-like resin-colored fungus layers. Confined to heartwood, usually of butt and roots.

Rot from the velvet top fungus is fairly common in Douglas-fir butts in California, but basal failures from it are rare except during extremely severe storms. In California red firs and in the pines, butt failures from this rot are more common, but they almost always occur during windstorms, mainly in winter. The rot usually stops within 12 feet of ground level. Only long-standing cases in old, slow-growing trees are likely to offer any recreational hazard.

Sap Rots in Hardwoods

Hardwood tree species are much more subject than conifers to pathogenic fungi attacking bark and cambium. Commonly known as canker organisms, these fungi in California are more likely to be active in low elevation or coastal recreational sites than in mountain districts. Once they kill the bark and cambium, the dead sapwood below becomes subject to sap rots. The decay can seriously weaken affected parts because it destroys the strength of wood in the outer part of the trunk or branch where strength is most needed.

Many different fungi may be active as sap rots, depending on the tree species affected and the location. Most of them fruit during the rainy season, producing either fleshy, mushroomlike fruitbodies that soon disappear or numerous small, thin, shelflike conks that are more persistent. The fruitbodies either appear on the bark itself or emerge through cracks in the bark or from exposed wood where branches have been removed, whereas the conks of heart rot fungi almost invariably appear at branch stubs or at openings connecting with the heartwood. A few sap rots that may also occur on dead parts of living trees have crustlike fruitbodies that may be produced under loose bark, in bark cracks, or as crusts over the bark surface.

Sap rot may be present without surface evidence of fruiting of the causal fungus. In such cases the condition of the bark will usually indicate that it is dead. Suspect sap rot under any areas of dead bark and investigate the condition if within reach.

Other Conditions Affecting Hazard

In addition to decays in living trees, various other defects or conditions may affect the safety of forest trees, or become a problem to the field inspector. The more common of these are described below.

Snags

Snags vary greatly in their stability, depending chiefly on the species of tree that they represent and on the climatic conditions of the area. But eventually all snags fall; when this may happen is unpredictable, except in broad terms. The shedding of dead branches or the breaking off of portions of the top or trunk of snags from weakening by decay is also common, especially in pine snags or those from the true firs.

Most snags fall or break off during winter storms, but this cannot be guaranteed. Moreover, at these times the direction of fall is uncontrolled, and damage may result to surrounding trees or installations. Deaths, injuries, and considerable aggregate damage to vehicles and structures have been reported from the falling of snags or their parts. On this basis it appears wise to regard all snags as potentially dangerous and to remove them in campgrounds and in similar areas of concentrated human use (fig. 9).

Dead Tops

In conifers, dead tops vary in type and causation and may or may not be hazardous. Old so-called spike tops in pine and Douglas-fir that give evidence of long-time existence are usually dry and resin-impregnated and have shown no greater hazard potential than any other part of the tree. Redwood, incense-cedar, and giant sequoia are other species on which the presence of old spike tops does not appear to seriously increase the hazard, on the basis of common experience.

At the other end of the scale are dead tops in white and California red firs, including dead volunteer tops. These defects are particularly common on white fir from about the Mokelumne River drainage southward in the Sierra Nevada as a result of a leafy green mistletoe that concentrates in white fir tops in that part of California. It is absent from firs north of the Mokelumne. The parasite eventually leads to the death of the infected tops, apparently assisted by fir engraver beetles. Volunteer replacement tops may in turn be infected and killed. Dead tops in firs may also result from the direct attacks of fir engraver beetles in the absence of top mistletoe.

Wood of the true firs is nonresinous, relatively nondurable, and readily attacked by decay fungi, which may soon weaken dead fir tops and cause them to break out during strong winds.

Aside from those on redwood, giant sequoia, and incense-cedar, bark-laden dead tops on living conifers should be regarded as potentially hazardous. The bark is evidence that dying has been relatively recent and that enough time has not yet elapsed to determine whether the top might ultimately be regarded as nonhazardous. Most dead tops do become hazardous, and therefore all recently dead tops except those on the species mentioned above should be so regarded.

Occasionally an old, weathered dead top that

Figure 9.—Snags before felling on a slope immediately back of a heavily used forest lodge. (National Park Service photo.)

looks sound may be weakened at some point by nest holes of woodpeckers. Thus what had previously been regarded as a relatively safe top may become potentially hazardous because of woodpeckers.

Broken-Out and Volunteer Tops

Most missing tops represent dead tops that have been weakened by decay and have broken off during storms. The break usually comes near the base of the dead part, because moisture retention in the dead wood is ordinarily better there than higher up. The higher location favors the activity of decay fungi in that zone. A short length of decayed trunk often remains below the break, but only in exceptional cases is it a safety risk. Normally it erodes away slowly. Concurrently the decay progresses, also at a slow rate, down into the heartwood of the part of the main stem below the break where the sapwood is still alive.

The loss of a top stimulates the production of one or more volunteer tops from near the upper limits of the remaining live trunk. These tops commonly arise from near the bases of uppermost live branches. In the true firs, they are often called bayonet tops or, when multiple, candelabra tops (fig. 10). Even though the main stem supporting these tops may have a decayed heart, they practically never break off and fall during the recreational season as long as they remain green and thrifty. They can become hazardous if dead. The only cases known of green volunteers failing have been from heavy loads of ice or snow during winter storms. Because of this possibility, the removal of such tops in the vicinity of buildings of year-round occupancy or centers of congregation for winter sports may be advisable.

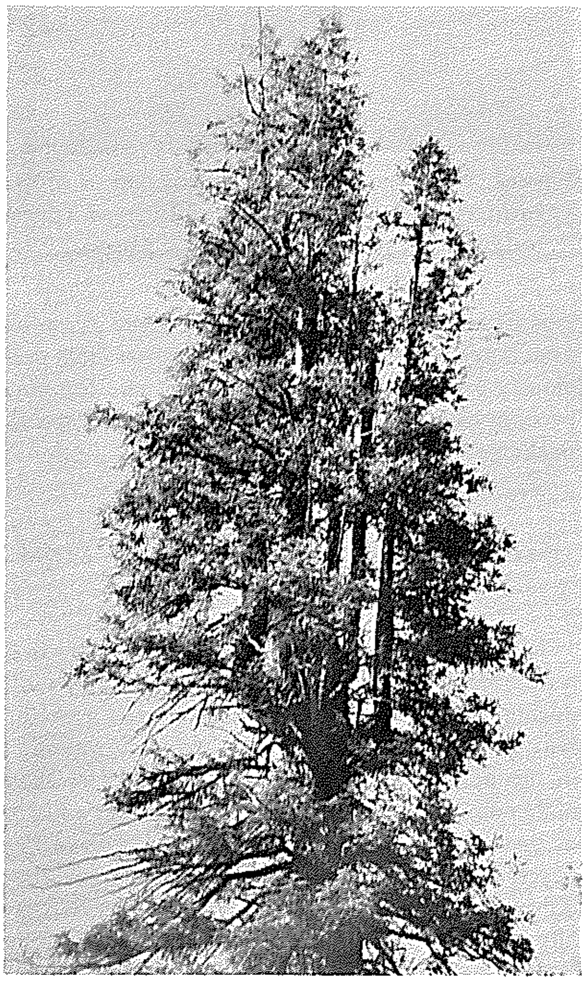

Figure 10.—Candelabra top formed by volunteers on a broken-topped white fir.

In older pines with broken tops, volunteer tops are sometimes slow to form. If the topmost green branches are thrifty in such trees, they should not be regarded as hazardous. In one or two areas numerous trees of this type have been needlessly removed in the past because it was thought that they were unsafe.

Forked Conifers

The term as used here refers to true forks and not to volunteer tops that have formed to replace a dead or broken top. The main stem divides, either from the division of the axis in the embryo stage before a terminal bud has formed, or as a result of injury to the terminal bud or shoot. In a few cases the forking habit appears to be genetic in origin; in others it may result from insect or other injury to the terminal bud or shoot. Forking from the latter cause is common in lodgepole pines in some parts of California.

The stems of a true fork generally diverge from each other at an acute angle and are joined at the base by a strong and tough crotch. As long as these members remain modest in size, they seem to offer no more of a hazard than the single stem of a normal tree. But as they become large and old, the diameter growth near their base brings mutual pressure on each fork base and ultimate flattening of each on that side, with layers of closely pressed bark between. If growth conditions are good, the individual forks may become long and heavy, exerting a strong leverage on the crotch during storm conditions. Thus a forked tree which presented no hazard when it was young may eventually become hazardous to at least a moderate degree when it becomes old. In rare cases, heart rot may extend up into a crotch, weakening it enough to cause breakage during a storm.

In very rare cases, mechanical splits may occur in the wood of a crotch without the presence of any decay and without the immediate breaking out of the individual forks. Such split crotches are distinctly weakened and should be considered as hazardous.

Dwarfmistletoe Brooms, Swellings, Cankers

Witches' brooms from dwarfmistletoe sometimes reach large sizes but, as long as they remain alive, do not appear to offer any hazard greater than that of normal branches. On white fir, old branch swellings sometimes become quite large and heavy and may be broken off by winter storms.

Main stem or trunk swellings, from stem infections by dwarfmistletoe when the host trees were

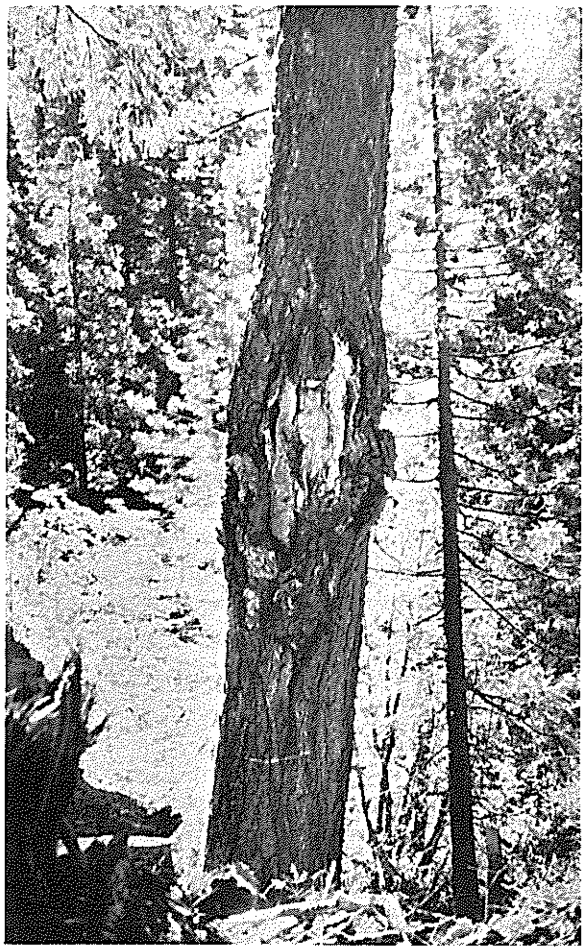

Figure 11.—An old dwarfmistletoe trunk swelling that has developed into an open, dead-faced canker on a white fir. This one would be rated as marginally hazardous.

young, may be quite prevalent on both white and red firs in some areas. As long as the swelling remains alive, it does not weaken the trunk, but eventually the cambium in the oldest part of the swelling dies. The bark over the dead part soon becomes broken, creating an open canker (fig. 11). Decay usually develops in the dead wood, although its progress in different cankers is very variable. The eventual result is a weakening of the trunk of the host tree at the site of the canker. The status of the weakening cannot be judged closely from surface indications, but when the width of the dead face approaches half the circumference of the swelling, the trunk may break at the canker site under the stress of heavy wind or snow conditions (fig. 12). Most such breaks occur during winter storms, but they can take place at other times. On this account it seems prudent to consider mistletoe cankers with a wide dead face on white or California red firs as potentially hazardous.

Open dwarfmistletoe cankers are sometimes found on the lower trunks of ponderosa and Jeffrey pines, but the wood around them becomes heavily resin-infiltrated, protecting them from decay. No case of breakage at such cankers is on record. They do not appear to contribute in any way to hazard.

Frost Cracks

In California, frost cracks are confined largely to white and California red firs. These cracks appear on the surface as raised lines of callus (frost ribs) in the bark, and follow the course of the grain of the wood in the lower trunk. Up to three or more cracks may be found on a single trunk, all

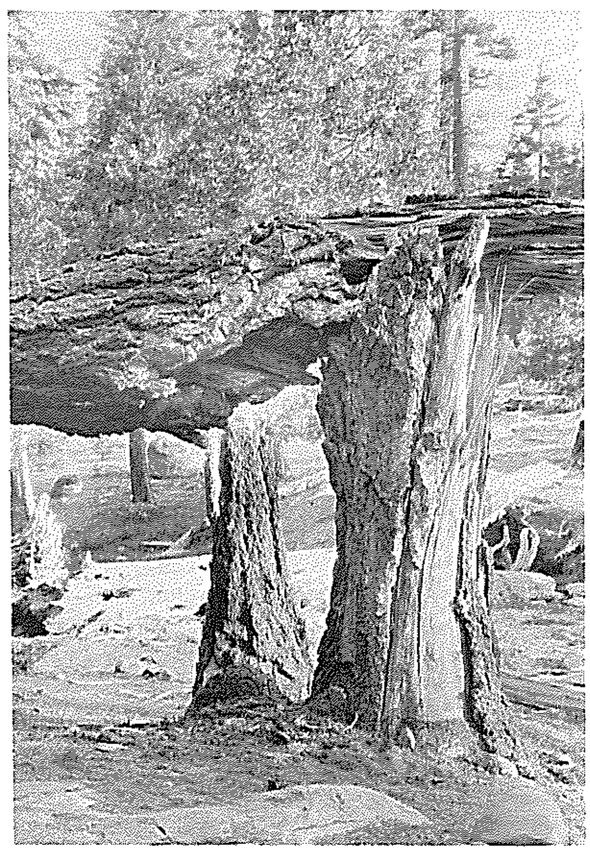

Figure 12.—A white fir trunk broken over at a large dwarfmistletoe canker. The long open wound on the trunk undoubtedly contributed to the failure.

starting near the butt and extending upward in a slightly spiraling course. They usually end within the first 16-foot log length, but sometimes extend into the second log.

Frost cracks are ordinarily formed by the contraction of wood in the outer parts of the trunk from freezing while the inner parts remain unfrozen. Thus they can form only in relatively sound wood and not in a trunk with extensive internal decay. They may sometimes be formed during freezing by the expansion of accumulated water in internal checks in the lower trunks of firs. The water accumulation in these internal checks appear to be an effect of associated wetwood in the trunk. Frost cracks are more common in the colder parts of California, such as east of the Sierra-Cascade crest, than in the milder parts.

Once formed, frost cracks ordinarily are closed by healing callus during the next growing season, but the callus is ruptured by contractive pull during the succeeding winter. This annual closing and rupture may continue over a period of years, but eventually the healing becomes complete over most frost cracks. A few stay open indefinitely and may be a source of leakage from the trunk.

Decay is often associated with frost cracks, but usually in limited amounts. Accordingly they do not indicate an unsafe condition within the tree.

Slime Flux

This term is applied to aqueous leakage, usually dark and rather foul-smelling, from openings or wounds in trees. It is relatively common in some types of hardwoods, but rare in conifers other than true firs. The presence of slime flux is not a sign that the tree is hazardous. It does not indicate decay in a tree because it is rarely associated with serious internal decay. However, it is sometimes present on trees in a generally decadent condition, although slime flux itself is not an indicator of decadence.

Slime flux may originate from either heartwood or sapwood and is caused by the presence of fermenting organisms in affected tissues, such as bacteria and yeasts. The organisms create an internal pressure by producing carbon dioxide gas as one product of fermentation. This pressure aids in forcing out excess water resulting from a wetwood condition within the wood. Wetwood is often present within a tree before the creation of the wound or opening through which the slime flux issues. It can occur in an otherwise perfectly sound tree. Bacteria are usually associated with the condition.

The slime-flux exudate often contains acids or aldehydes, some of which may be toxic to callus tissues over which the liquid flows. This action may interfere with the healing of the lower part of the wound. In any individual case a check can be made for toxic action by examining the callus over which the exudate has been flowing. If the callus there is alive and shows no signs of damage, one can assume that the flow is having no toxic effect. If indications of toxic action are found, they do not mean that the tree with the slime-flux condition is hazardous, but only that the opening through which the flux issued will be slow to close. Some internal toxic effect, limited to the particular column of wood through which the flow of exudate is occurring, may also be present. The effect does not promote decay; if anything, it inhibits the development of decay fungi.

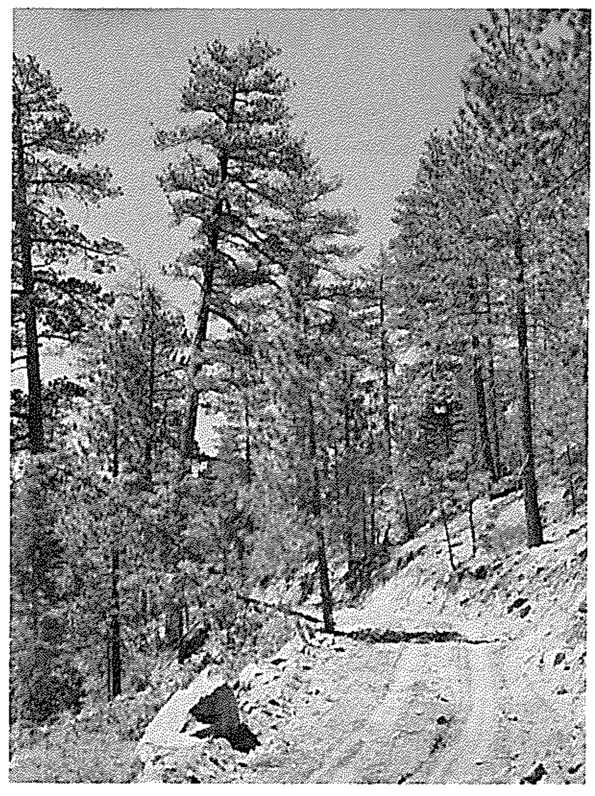

Figure 13.—A leaning pine rated as offering a low potential hazard because the tree grew in this shape. The road toward which it leans receives only limited use.

Leaning Trees

The safety of leaning trees is often a question in recreational areas and around dwellings in wooded districts.

If a tree has grown in a leaning position throughout most of its life, it develops structural compensations for the lean as it grows. Instead of normal wood, special tension and compression wood is formed at places of stress. This wood is structurally stronger than the wood in a tree that is fully vertical at these locations. Figure 13 shows a leaning tree of this type that is of low potential hazard as long as it remains sound. But there are occasionally trees that have a lean because of root loosening caused by an outside force, such as heavy wind, flood waters, or a falling tree or snag. Such trees have not grown through life in adjustment with the lean and should ordinarily be regarded as potentially hazardous.

There are also cases in which trees have developed with extreme leans but are not particularly hazardous while small, if in a snow-free locality. Such trees are usually confined to understory hardwoods. As these trees become larger and lengthen, however, the leverage exerted by the lean becomes greater in proportion to the strength of the wood, and they may eventually fail. For example, in a coastal campground a cottonwood having a lean exceeding 45 degrees finally broke even though the trunk at the break appeared to be sound. The tree was located near a campsite which, fortunately, was unoccupied at the time it fell.

An old open fire wound may occasionally render a leaning tree potentially hazardous if the wound is in line with the axis of strain from the lean and if advanced rot is present in the wood back of the wound. This is particularly the case if the fungus causing the decay can also cause root rot, as *Fomes annosus* may do.

Figure 14.—A black cottonwood, with root anchorage impaired by high water in an adjoining stream, fell across this camp table. A smaller incense-cedar was carried down with it. (National Park Service photo.)

Asphalt Pavement Over Roots

In some more heavily used recreational areas, roads, parking areas, and similar places of concentrated travel have been paved with asphalt to check dust and mud. An attempt also has been made to leave as many native trees as possible for esthetic reasons and to retain as much of the park-like character of the area as practicable. Consequently, the asphalt layer often covers portions of the root system of adjoining trees. In some instances, the pavement extends over a large part of the root spread.

The pavement prevents moisture and nutrients from the decomposition of forest litter from entering the covered soil, but it also prevents the loss of moisture from the soil in the form of vapor. In a soil with a deep source of moisture, such as a water table, considerable moisture moves through the soil in a vapor phase. Because of its dark color, asphalt loses heat readily by radiation during night hours and cools enough to cause moisture to condense on its under surface. This loss tends to offset the absence of moisture infiltration from above. Consequently, trees surrounded by pavement often do not suffer as much from lack of moisture as popularly supposed.

The chief detrimental effect of pavements covering roots appears to be in the reduction of aeration. Roots need a continuing supply of oxygen to remain healthy, and they do not get enough in a soil covered by an asphalt pavement. A weakened condition results, and the roots become susceptible to root fungus attack. Roots of California oaks, when in a declining state, are particularly susceptible to the fungus *Armillaria mellea,* so much so that a common name of the organism is the "oak root fungus." If this fungus is present anywhere in the portion of the root system of an oak covered by asphalt pavement, the parasite is likely to spread rapidly to the root crown at the base of the tree and to cause ultimate death or failure. In conifers, pavement over major parts of root systems is likely to induce bark beetle attacks.

Native Tree Species and Hazard

The native tree species listed below include most trees likely to be found in public campgrounds and in portions of recreational areas receiving concentrated public use in California:

Common and Scientific Names of Species[1]

alder	*Alnus* spp.
aspen	*Poulus tremuloides*
California-laurel	*Umbellularia californica*
cottonwood	*Populus* spp.
Douglas-fir	*Pseudotsuga menziesii*
fir, California red	*Abies magnifica*
fir, white	*Abies concolor*
Incense-cedar	*Libocedrus decurrens*
madrone, Pacific	*Arbutus menziesii*
oak, California black	*Quercus kelloggii*
oak, California live	*Quercus agrifolia*
pine, digger	*Pinus sabiniana*
pine, Jeffrey	*Pinus jeffreyi*
pine, lodgepole	*Pinus contorta*
pine, ponderosa	*Pinus ponderosa*
pine, sugar	*Pinus lambertiana*
redwood	*Sequoia sempervirens*
sequoia, giant	*Sequoia gigantea*
tanoak	*Lithocarpus densiflorus*

Alder

Principal hazard: Root loosening by water.

In California, alders are primarily streamside trees and offer practically no hazard unless partially washed out or undermined by high water. This may make them subject to uprooting during high winds.

Aspen

Principal hazard: Killed trees or tops.

As a tree of recreational areas in California, aspen is found chiefly along the eastern slope of the Sierra Nevada. It does not stand up well under human use. Also in the past it has been subject to at least one wave of decline, probably of climatic origin, which resulted in the ultimate death of thousands of trees. This decline was not accom-

[1] Little, Elbert L., Jr. Check list of native and naturalized trees of the United States (including Alaska). 472 pp., Washington, D. C.: Forest Service. 1953.

panied by a high degree of hazard, however, because climatic conditions in which aspen is found in California do not favor rapid decay of the species. Dead trees are ordinarily cut for fuel soon after death. Locally a heart rot from the false tinder fungus *Fomes igniarius* is sometimes common in restricted patches of aspen, but for the most part has not weakened affected trees enough to be a safety factor.

California-Laurel

Principal hazard: Dead branches.

This species is not extensively represented in California parks and campgrounds, but is rather common in some north coast recreational areas. The heartwood near the butt is very commonly decayed by the fungus *Fomes applanatus,* but the tree is characteristically a vigorous grower. Its sapwood is usually strong enough to support the trunk and prevent failure even though decay in the heartwood may be well advanced. Accordingly the presence of *F. applanatus* conks near the base of a tree should not be regarded as an indication that the tree is unsafe. The conks are shelf-like and woody, dark brown on top, and have a whitish pore surface underneath composed of small round pores.

Cottonwood

Principal hazards: Cankers, heart and sap rots, undermined roots.

The wood of trees of this group is soft and quite brash, as well as having little resistence to decay. Cottonwoods are also subject to several bark canker diseases that may be followed by decay. On this account they should be inspected at least annually for defects that could lead to breakage. Prompt action should be taken to remedy any potentially hazardous conditions found. Near streams the undermining of root systems during high water should be watched (fig. 14).

Douglas-fir

Principal hazards: Usually none.

In some parts of the Pacific Coast, a root rot that leads to windfall is quite common in second-growth Douglas-fir, but the disease has not been found in this species in California. Even trees with basal red-brown butt rot are usually strong enough to be safe except under very extreme wind conditions when any forest area is likely to be unsafe. The high mechanical strength of the wood of this species contributes to its safety.

Fir

Principal hazards: Primary and volunteer dead tops, trunk cankers from dwarfmistletoe, trunk rots, butt and root rots.

White and California red firs are more subject to defects that may render them hazardous than almost any other native conifers in the State.

Dead tops, either from mistletoe or the work of fir engraver beetles, are very common in white fir, particularly in stands located south of the Mokelumne River drainage. Most of these dead tops later decay near the base and fall out during windy weather, creating a hazard.

In areas where dwarfmistletoe has been present for the life of the stand in white and red firs, old swellings of the trunk from stem infections by the parasite are likely to develop into open cankers (fig. 11). The exposed wood in these cankers is often invaded by decay fungi. The resulting weakening of trunks may end in their breaking over, usually during storms.

Old, long-standing cases of trunk rot from the Indian paint fungus *Echinodontium tinctorium* may occasionally weaken fir trunks enough to cause them to give way during storms, especially when the rot extends down into the tree butts. Combination defects, such as sap rot working in the outer shell of trees hollowed by trunk rot, are particularly likely to lead to trunks breaking over under the stresses of wind and a snow load. Usually these failures occur outside of the camping season, but they can damage buildings that may be located in the vicinity.

In white fir, either of two root and butt rots may be present: the shoestring fungus *Armillaria mellea* or the Fomes root fungus *Fomes annosus.* Both parasites cause white rots that eventually may hollow out the tree base and rot out portions of the roots. The weakened root system is likely to give way during high winds, causing the tree to become a windfall. In rare cases, an old decadent fir with either of these two rots may give way during warm, windless night or early morning hours. In most cases where these rots are present, they occur in trees with old, open basal fire wounds, through which the decay fungi originally entered. Occasional instances are found, however, in which the fire wound that originally served as the entrance court has become healed. Occasionally, also, the causal fungus may have entered the butt of the tree through a root, and no evidence of an open or closed wound will be present. Extensive root destruction in such trees is usually accompanied by a deteriorated crown, many dead branches scattered through it, and by very slow current growth. But if dwarfmistletoe is present, it can produce substantially the same crown symptoms and reduced growth. A person inspecting for possible hazards must try to decide whether such symptoms in a particular tree suggest root damage or the presence of dwarfmistletoe.

California red fir also is subject to a red-brown cubical butt and root rot from the velvet top fungus *Polyporus schweinitzii.* Root damage by this fungus is ordinarily not as extensive as it may be from the white-rot fungi previously mentioned. No case has been reported where windfall from this butt and root rot has resulted primarily from root failure, but occasional cases are found in which red firs have broken over at the base from this rot combined with a large open fire wound. In both white and red firs, similar basal failures may result from old, long-standing cases of mottled heart rot from the yellow cap fungus *Pholiota adiposa* and in red fir of brown cubical rot from the sulfur fungus *Polyporus sulphureus*.

Occasional white firs are encountered which appear very "rough" on the outside. An inspector may conclude that these trees must be very defective even if no conks are showing. They are usually former "wolf" trees, having large limbs that become heavy stubs as the lower crown dies off. Actually, such trees are often surprisingly sound and should not be regarded as hazardous unless other indications than the "rough" appearance are present to indicate a possible hazardous condition.

Slime flux from the lower bole is sometimes present in firs and is often mistakenly regarded as the sign of a dangerous condition, but it rarely is. In some districts, frost cracks, which are marked by somewhat spiraling lines of callus in the bark, occur along the grain in the lower trunk. The cracks do not indicate a hazard. Decay is often associated with them but rarely in extensive amounts.

Giant Sequoia

Principal hazard: Falling limbs.

A few cases, widely spaced in time of occurrence, are known in which giant trees of this species have fallen. In addition, a few standing sequoias are recognized as risks to fall, and thus present individual hazard problems. For the species as a whole, however, the danger from falling trees is remote. Practically the only hazard is from the falling of occasional huge limbs broken off by snow or lightning. We know of no cases of death or injury from such limbs.

Incense-Cedar

Principal hazard: None.

The wood of incense-cedar is relatively brash. This characteristic results in the breakage of dead limbs under the weight of snow, but uprooting and the breaking of tops or trunks is uncommon except in exposed locations. To date it has not proved to be hazardous in recreational areas. Pocket dry rot is common in the heartwood of the species. But under normal stresses, when affected trees are part of a stand, heartwood weakened by the rot has not been the cause of appreciable storm breakage.

Oak and Tanoak

Principal hazards: Sap rots of branches and trunks, heart rots, snowbreak, root disease.

The oaks as a group have been responsible for more accidents or potential accidents in California recreational centers than any other type of trees.

The native California black oak is often associated with conifers, particularly with pines. It is not a very long-lived tree and is not shade tolerant. Surrounding pines outstrip it in height sooner or later, bringing on gradual decadence in the oak because of side shade. In this condition the roots are quite susceptible to the shoestring fungus *Armillaria mellea,* also a cause of common butt rot in oaks. The tree is gradually weakened at the base by decay until it fails. Most known cases of oaks toppling, either during high winds or in periods of complete calm, have resulted from rot in the butt or roots by this fungus.

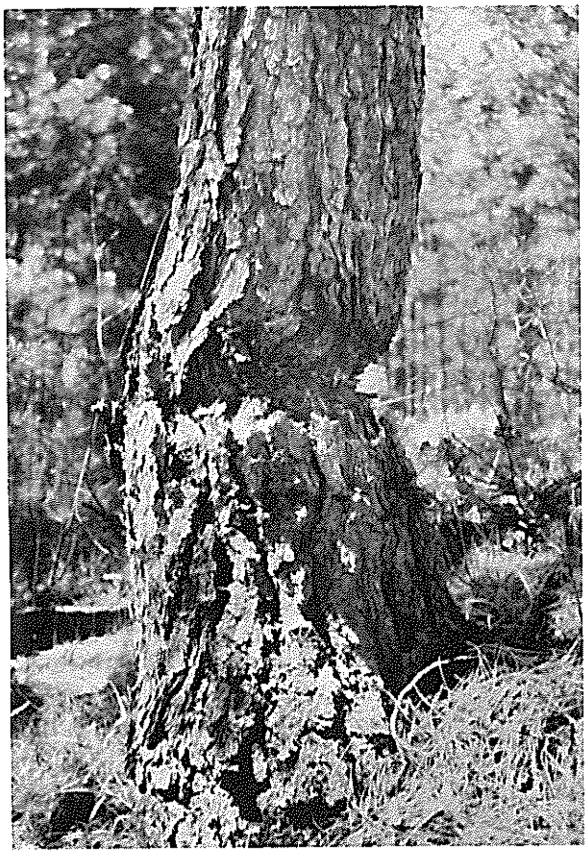

Figure 15.—A horizontal canker, probably from a tree rust, on the lower trunk of a ponderosa pine. Breakage at the canker sometimes occurs when the depression is deep and located higher than 16 feet from the ground.

Pacific Madrone

Principal hazards: Dead limbs and trees.

Madrone wood is relatively strong, and the species has given little trouble from mechanical failure. In some areas this tree has been subject to relatively rapid dieback and death, which has necessitated the removal of many trees in coastal districts. More than one cause seems to be involved in the mortality, the reasons for which are not yet completely understood.

Pine

Principal hazards: High horizontal cankers, heart rot from fire wounds, large low-crotched forks.

Damage to life and property from pines, aside from the hazard of falling green cones of such heavy-coned species as Coulter and sugar pines, has occurred almost exclusively during severe storms. These storms have been intense enough to cause the breakage of much sound wood or the uprooting of trees with relatively sound root systems. The sapwood of most California pines is quite thick in proportion to the total cross section, and the heartwood tends to be relatively sound except for occasional old, overmature specimens. In these trees the rot is usually in association with old fire wounds. On the other hand the wood is mechanically not as strong as in some other conifers, such as Douglas-fir. Consequently the wood of pines may break under the stress of exceptionally high winds, whereas species with tougher wood can be expected to remain intact when under the same stresses.

Any trunk abnormality that tends to seriously disrupt the normal round form at some particular point is likely to increase the possibility of breakage there. Thus, in at least one district in California, deep, horizontal cankers at some distance from the ground have resulted in an occasional breaking over of the cankered trunks at the canker during severe storms. On the other hand breakage has not been noted from cankers of the same type located within a few feet of the ground (fig. 15). The wood around these cankers (which are probably caused by a tree rust) is hard and tough. Only when the canker depressions become deep and occur 16 or more feet from the ground do they seem to weaken the trunk of the affected tree enough to cause breakage in occasional cases during severe windstorms.

In a few cases large forks in pines have broken out during heavy winds, and in one of these a fatality resulted. However, this does not mean that all forked pines should be considered hazardous.

The wood of pines on marginal interior sites near the zone of transition to desert conditions is likely to be more brash than normal wood.

Redwood

Principal hazards: Falling dead branches.

In old-growth redwood the chief hazard seems to be from falling dead branches or stubs. The sources of these parts are usually so far from the ground and crowns are so dense that detection is difficult. The tendency now is to move campgrounds away from old-growth stands. Young second-growth redwood is relatively free from this type of hazard.

One case is known of a fatality from a redwood that fell because of a strong lean and a base that was burned out on all but one side. The strength of the wood is such, however, that redwood trees with burned-out butts (commonly referred to as "goosepens") are ordinarily not hazardous.

Examining Trees for Hazards

Recommended Equipment

Axe, 3½-lb., single bit.—For tapping bark to detect dead cambium or for sounding tree butts or case-hardened surface wood in open tree wounds for hollowness or cavities. A single-bitted axe is better adapted than the double-bitted type for these purposes.

Increment borer, 12- or 15-inch.—For determining the current rate of growth of trees or the thickness of sound wood in tree butts with heart rot. A long twist bit, such as a car bit, may be substituted for the latter purpose.

Field glasses.—For checking the condition of tops in tall timber.

Shovel.—For checking the bark surface below ground for the presence of "shoe-strings" where the Armillaria fungus is suspected, or in sampling below ground for cambium killing by *Fomes annosus*.

Making the Examination

Usually the trees of any particular area will be confined to not more than two or three main species. Before starting an examination, review the kinds of defects likely to be associated with the species that could render them hazardous. Also note whether the timber is young and thrifty or old and declining in thrift, because a general condition assessment of this sort will have a bearing on what defects to anticipate and to what extent they may render individual trees hazardous. The chances for the development of serious defects are cumulative with age in a tree. Heart rots, for example, are usually minor in a young stand, but may prevail in an old stand. Basal fire wounds, open or closed, through which decay fungi often have entered are found chiefly in trees over 80 years old, when woods fires were frequent in California.

Be systematic in the examination, and cover all sides of each tree. On individual trees begin the inspection either at the top and proceed downward or at the butt and proceed up, but standardize on one procedure or the other and follow it consistently.

Checking the Top

At the top check for:

- Dead tops that may become weakened by rot and break off.

Checking the Crown

In the crown look for:

- Hanging broken or cracked branches that should be removed.
- Signs of general decadence, such as short and weak growth, and the presence of dead branches, either old or recent, scattered through the crown.
- Evidences of split crotches, both in hardwoods and between the forks of forked conifers. Unless the split is very recent, it will be marked by lines of healing callus similar to those that form along frost cracks.
- Evidences of dead cambium and associated sap rot on branches or trunks of hardwoods.

Checking the Trunk

On the trunk look for:

- Fungus conks or the remains of old weathered conks, indicating the presence of heart rots.

- Evidences of rot and hollowness in the heartwood of hardwoods where large branches have been sawn or broken off.
- Large open wounds showing rot within.
- Dwarfmistletoe swellings with exposed dead wood on the trunks of firs.
- Cankers on the main trunk deep enough to weaken it at the point where they occur.
- Excessive flattening of the trunk from any cause.

Checking the Butt

At the butt check for:

- Wounds, open and closed, from fire or mechanical injury and associated rots.
- Conks, or remains of conks, indicating basal decay, including those from roots near tree bases.
- Dead cambium.
- Reduced firmness of rooting from water or wind action.

The above list does not include every defect or indicator that might be encountered and that could influence the safety of the tree, but most of the major ones. Be alert for anything that might have a bearing on safety whether included in this list or not.

Checking for Heart Rot

One of the most common defects to look for and assess in old timber is heart rot or hollowness of the trunk resulting from it. Expect this defect particularly in trees bearing conks or showing old wounds, either open or closed. Occasionally, however, an old tree will be hollow with little outside evidence of heart rot (fig. 16). Keep in mind that a tree need not be large to be hollow.

The rate of recent diameter growth is a useful index of the probable safety of any tree with heart rot or hollowness. Trees that are making good growth will have thicker sapwood than those growing slowly and should be less likely to fail. The condition of callus growth around wounds is also of indicator value. If growth of the tree is good, callusing will be good and the bark over the callus will be thin and healthy in appearance. The crown will also be thrifty.

One test for heart rot or hollowness of the lower trunk consists in "sounding" the trunk by striking it sharply with the poll of an axe. If hollow or decayed and the surrounding wood is not too thick, the blow on the trunk will produce a hollow sound distinguishable from that produced when a solid trunk is struck in this manner.

For a more positive method of testing for hollowness, sample the lower trunk with an increment borer. If the borer breaks through into rot or a hollow resulting from the collapse of rot, the extracted core will give the thickness of the surrounding wall of solid wood at that point and also an opportunity to judge the rate of recent growth. If an increment borer is not available, a long twist bit may be used, but it will not give a very good index of recent growth. The chief disadvantage with sampling with either tool is the time and energy required to make the boring, which tends to limit its use to important questionable cases.

Do not rush a hazard inspection. In most recreational areas you are dealing with trees that are much more valuable in place than trees in the usual timber sale area and that from the practical standpoint are irreplaceable. On this account an *inspection for hazardous trees should not be regarded* as the equivalent of timber marking on the usual timber sale but rather a matter of individual tree diagnosis, more comparable to a health checkup in humans than to ordinary marking for cutting in a timber stand. Allow as much time as is needed to be reasonably sure of the decisions made. If a boring is needed, take time to make it.

Checking for Dead Cambium

Checking for dead cambium at the butt of the

Figure 16.—A 16-inch diameter lodgepole pine broken over in a campground from hollowness caused by rot. Only 1¼ to 1½ inches of sound wood remained on the outside. No conks were present. Recent growth had been very slow, over 100 rings per inch.

tree is particularly important when examining decadent oaks. The most practical way of doing this is by tapping the bark on the outside with the poll of the axe. Bark over dead wood soon separates from it and emits a shallow, hollow sound when tapped. Dead cambium near the base may be caused either by insects or fungi. Decay of the dead area can be anticipated, if it is not already under way, and further decadence of the tree is to be expected.

Tapping or pounding the dead wood surface with an axe is also useful in determining how solid the wood is within large open basal wounds. Under climatic conditions often prevailing in California, exposed wood in open wounds on trees tends to "case-harden" in the outer layers, remaining relatively sound there even though the wood underneath this layer may be in an advanced state of decay. Sounding on the surface wood with the poll of an axe will often disclose such a condition.

If pavement covers a substantial portion of the soil above the area of root spread of oaks, this may create favorable conditions for the spread of *Armillaria mellea* in the roots. For this reason oaks with pavement around or near them should be closely inspected during tree safety examinations for any evidence of this fungus or of fungus-killed cambium. In particular, parts of the butt facing the paved area should be examined in detail to determine if the fungus has progressed into them along the roots from under the pavement. If the fungus has reached the tree butt and is still active, a felt of white mycelium will be present between bark and wood in the invaded part of the butt. Thin white wefts of hyphae, usually fan-shaped in pattern, will be produced between layers of the bark and will be noticeable when the bark is cut, split, or broken apart.

If dead areas of wood and bark are found at the base of oaks and *Armillaria mellea* is suspected as the cause, check for the presence of the fungus by removing a few shovelfuls of soil from next to the dead area and looking for the blackish, flattened rhizomorphs ("shoestrings") of the fungus over the bark surface below ground level. Rhizomorphs are not invariably produced by an established infection of *Armillaria mellea;* if they are found they provide positive evidence that the fungus is there.

Judging The Hazard

In actual practice the examination and assessment for safety are carried out together. Because of the wide differences between individual trees and their surroundings, each tree constitutes an individual case that requires an individual decision as to its safety.

Rots

Earlier we pointed out that the application of strength formulae to defective live trees can be only approximate because of the lack of uniformity of the defect. An internal column of heart rot is seldom uniform in radial dimension, either horizontally or vertically. It is also difficult to judge from the outside how defective a tree is within

Table 2.--Minimum safe standard for defective trees[1] *applied as average thickness of outer sound wood of the trunk with center rot or hollow representing 70 percent of the total wood diameter, equivalent to one-third loss in strength*

Diameter of tree inside bark	Thickness of sound wood[2]	Diameter of tree inside bark	Thickness of sound wood[2]
Inches	Inches	Inches	Inches
16	2.5	44	6.5
20	3.0	48	7.0
24	3.5	52	8.0
28	4.0	56	8.5
32	4.5	60	9.0
36	5.5	64	9.5
40	6.0	68	10.0

[1] *Assumes no modification is applicable.*

[2] *Figures rounded to the nearest half inch.*

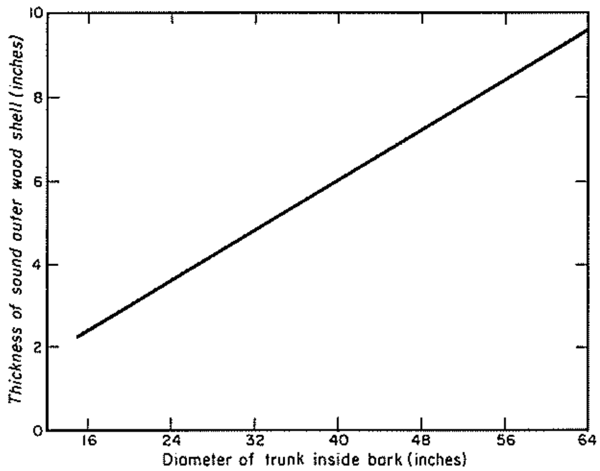

Figure 17.—Approximate radial thickness of outer sound wood required in a trunk with center heart rot if the strength reduction is not to exceed one-third.

and where the zone of maximum weakness may be located. Some of the most pronounced cases of failure from trunk rot ocur in trees that show little surface indication of the rot and in which loss of mechanical strength of the trunk has reached as much as 85 percent.

Field experience indicates that a conifer can suffer up to one-third loss in strength—equivalent to approximately a 70 percent loss in total wood diameter inside bark (fig. 3)—without materially affecting the safety of a tree if the weakening defect is heart rot uncomplicated by other defects. This standard can be applied most conveniently in the field as the thickness in inches of sound wood outside of the rot column or hollow (fig. 17 and table 2). If the indications are that the layer of sound wood is thinner than that shown in table 2 for a comparable wood diameter and there is no apparent reason for modifying the strength-loss ratio, the tree should be marked for cutting. A somewhat stricter standard may be advisable for conifers in highly exposed situations or in the vicinity of buildings occupied all year.

The one-third strength loss limit proposed above as allowable is by no means absolute. It represents a chosen average value, including a safety allowance, but not a limit based on specific studies or records because no such data exist. We regard it as the best working estimate we can make of a satisfactory average limit to serve until a better-grounded standard becomes available.

A specific standard of loss in strength, such as one-third, is less applicable to hardwoods because of the features of this group mentioned earlier: (a) the difference in basic form between hardwoods and conifers, (b) the strong and variant influence of leverage on the breakage potential, (c) the high mechanical strength of the wood of many hardwood species, and (d) the fact that trunk failures, aside from those near ground-level from the honey fungus, are relatively rare in occurrence except in weak-wooded species such as the poplars. The condition of the main branches is often more important from the safety standpoint than the condition of the main trunk. Thus the decay at stump height in the oak shown in figure 8 does not render that part of the trunk hazardous, but the hollow in the section shown of a main branch does render the branch unsafe.

In virgin stands of true firs and occasionally in other timber, trees may show both conks on the trunk and old basal fire wounds. Almost invariably in the firs and commonly in other species, except incense-cedar, the rot associated with the trunk conks will be different than that associated with the fire wounds. The two rots may join in the trunk heartwood, but they will not overlap, and the development of each will be independent of that of the other. But both will be limited by the radial limits of the heartwood unless the causal fungi can invade the living sapwood, which is usually not the case (fig. 18).

The average person tends to overrate the hazard potential of trees with perennial conks, such as those of the Indian paint fungus, on the trunk as compared with defective trees without visible conks. A tree that is cull commercially is not necessarily a hazardous tree, as evidenced by the numerous white and red firs that have stood without failure for many decades, even though they bear Indian paint fungus conks.

In the case of trunk rots that center at some distance from the ground, direct sampling to determine the thickness of the outer wall of sound wood is not practicable. Accordingly, decisions must be made from indirect evidence. In the case of the Indian paint fungus only conk-bearing trees with (a) conks more than 6 inches wide, (b) the highest and lowest conks separated by 10 feet or more, and (c) current radial tree growth slow, indicating a thin sapwood, should be regarded as possibly hazardous under average conditions. In areas occupied year-round or in especially exposed situations, somewhat more stringent standards may be justified.

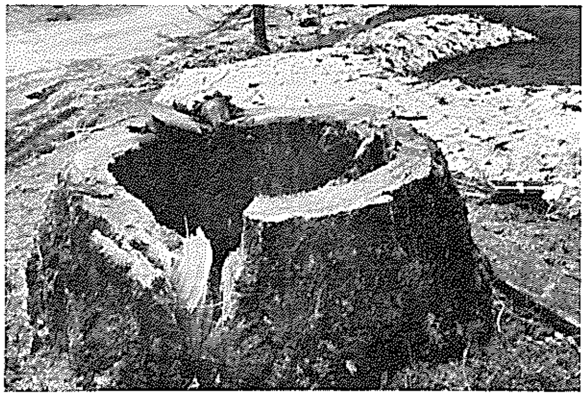

Figure 18.—Hollow from a white rot at the stump of a 67-inch d.b.h. white fir. About 3 inches of sound wood remained around the outside. A second heart rot higher in the trunk caused the upper 90 feet to disintegrate when the tree was felled. (National Park Service photo.)

Conks of the ring scale fungus on the trunks of Douglas-fir and other conifers, and of *Polyporus amarus* or its shot-hole cups on incense-cedar are not signs that the trees are unsafe. The same applies to conks of the false tinder fungus on aspen trunks *in California*.

For butt rots that do not seriously involve the roots in trees, such as brown rot caused by the sulfur fungus, a reasonably close estimate of the thickness of the sound shell can be obtained and a decision made based on such guides as table 2 (fig. 19).

So far as known, all cases of basal failures of trees from advanced butt and root fungus infections that have resulted in accidents or near accidents on recreational areas have been in trees with unmistakably large basal hollows and in a plainly decadent condition. Oaks that have toppled from weakening by the honey ("oak root") fungus have had as much as 85 percent of the basal wood destroyed. This destruction was often accompanied by patches of dead sapwood at the butt. Primarily, however, it is the killing of roots that causes the failure, both in oaks affected by the honey fungus and in firs weakened by the Fomes root fungus. Where decay typical for these fungi is present and the trunk contains large openings into a central hollow, it is often fairly evident that the decay extends into the roots. Recent radial growth of such trees is normally slow, and the crowns are in poor condition. Regard trees showing these defects and in this condition as hazardous and mark them for removal. This is particularly true if Armillaria "shoestrings" are found over the bark surface just below ground level in oaks. In firs affected with

Figure 19.—About 83 percent of the wood in a cross section of this oak trunk had been destroyed by decay, equivalent to about 65 percent reduction in mechanical strength. The tree would be rated as potentially hazardous. (National Park Service photo.)

the Fomes root fungus, open basal fire wounds through which the decayed internal condition of the butt can be seen may not be present. In these cases, if a "sounding" test with the axe does not indicate a hollow butt, the tree should be bored. In judging trees, also look for such indicators as slow growth and a decadent condition of the crown not attributable to dwarfmistletoe. Consider as hazardous those with advanced cases of root rot as judged from the combination of indicators.

Sap rots in living trees are usually local and, except in the case of oaks attacked by the honey fungus, are in sapwood killed by some other cause. When rots occur on branches, they normally affect the safety only of those branches and not that of the entire tree.

Sap rots on trunks already weakened by advanced cases of heart rot may render the trees highly hazardous if the rot in the sapwood approaches half of the circumference of the tree in extent. Such cases are sometimes hard to detect, but where they can be recognized mark the affected tree for removal. Trunks with excessive areas of dead sapwood, whether or not associated with heart rot, are likely to be present only on very decadent trees, which should be condemned and removed.

Other Defects and Conditions

The hazard status of the defects or tree conditions listed below has already been described. The ratings indicated there are summarized below. The reader should remember that in some cases no sharp distinction exists between the hazardous and nonhazardous classifications.

Nonhazardous	**Hazardous**
Brooms, dwarfmistletoe, live.	Brooms, dwarfmistletoe, dead.
Cankers, dwarfmistletoe, on pines.	Cankers, dwarfmistletoe, on trunk swellings on true firs, when the dead face of the cankered area approaches half the circumference of the swelling.
Cankers, horizontal, on ponderosa pines, when low on trunks.	Cankers, horizontal, on ponderosa pines, when deep and above 16 feet from the ground.
Forked conifers; in general (see also: Tops, volunteer).	Forked conifers, when forks are long and heavy, and the crotch is at right angles to the direction of heaviest winds.
Frost cracks.	
Leaning conifers, that have grown in a leaning position.	Leaning conifers if (a) the lean has been caused by an outside force, and (b) an open wound with advanced decay and poor calluses is in line with the direction of lean.
	Leaning hardwoods, if the lean is extreme and the leverage great for the strength of the wood.
Pavement, asphalt, over roots; not hazardous in itself but favors the development of hazardous conditions.	
Slime flux.	Snags.
Swellings, dwarfmistletoe, live.	
Swellings, dwarfmistletoe, cankered, on true firs if canker is small (compare under "Cankers").	
Tops, broken out, if top branches are thrifty.	
Tops, dead spike, on giant sequoia, incense-cedar, and redwood, if not structurally weakened by woodpecker holes. Also on pines and Douglas-firs if old, without bark and deeply weathered.	Tops, dead, on other species, or bark-covered on pine or Douglas-fir (includes dead volunteer tops).
Tops, volunteer, if live and thrifty.	Tops, volunteer, live, of borderline hazard in areas of winter use.

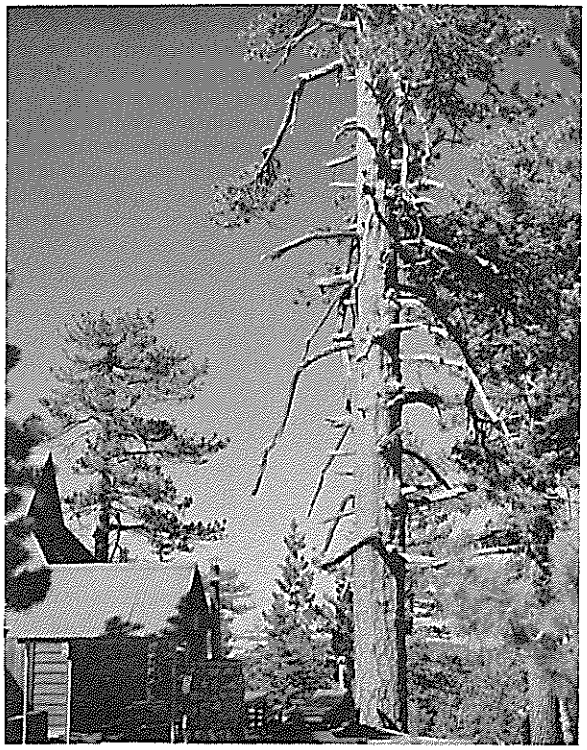

Figure 20.—The dead limbs on this veteran pine emphasize the rugged character of the mountain-top location, but the long ones are a hazard to users below. If these long limbs were removed, the danger can be abated without sacrificing the rugged appearance of the tree or incurring a rot hazard.

Multiple Defects or Conditions

Two or more defects occurring together may sometimes render a tree hazardous when it might not be if it had only one defect. Cases already mentioned are the combination of a sap rot and a heart rot, and one of a leaning tree with a large basal wound in line with the direction of lean. Other combinations are possible and should be looked for in the course of inspections.

Inspection and Hazard Reduction

The necessity of tree inspections for safety in recreational areas differs somewhat because of differences in the length of season of use, the intensity of use, and the character of the stand. In general, a programed inspection probably should be made once a year, supplemented by special inspections whenever required by circumstances, such as the occurrence of an abnormally severe storm that is known to have caused general damage in the district. A record of each inspection should be carefully made and preserved in case the safety of any tree examined should later be questioned.

Until recently the standard method of eliminating tree hazards in forest recreational areas has been to fell the affected trees. From a practical standpoint such an action is irreversible and results in the gradual depletion of cover on the area involved. More than one long-established campground now receives only sporadic use because the loss of tree cover makes the area too open to attract campers.

One means of reducing this type of recreational value erosion is to remove or correct the hazard without sacrificing the tree. Smaller dead tops, broken and hanging branches, and dead limbs with sap rot are types of defect that can be corrected in this manner. Cracked crotches and limb splits, particularly in hardwoods, can also sometimes be repaired by the use of tie bolts.

Work of this kind requires an experienced and properly equipped tree man or crew, but has the advantage of retaining the tree and often of eliminating the greater part of the cleanup work involved when an entire tree is felled. At least one National Park in California now has its own trained crew for this type of hazard correction. In other instances, jobs have been handled by commercial tree repair firms under contract. Regardless of how undertaken, this type of corrective treatment deserves increasing consideration where appropriate types of defect are involved.

Above all, intelligent consideration should be given to all aspects presented by an individual case before deciding on the best means of eliminating the hazard that it presents. For illustration, the grizzled old pine in figure 20 stands in a mountain-top recreational area receiving year-long use in southern California. Large trees are scarce in the area, and thus unusually valuable. But this rugged-looking tree also adds much to the general character of the site. Its long dead limbs are a hazard to users of the area, but they also demonstrate that climatic conditions there are very unfavorable for decay or else that the tree is very resistant to it. Otherwise it would not have such long limbs. The short dead branch stubs are eroding slowly and show no evidence of contributing to the risk.

The danger could be removed by felling the tree or by sawing off all dead branches. But either practice would entail an unwarranted destruction of plus values. The most acceptable treatment for this tree would appear to be breaking off mechanically the long dead branches that create the hazard, and allowing the broken stubs to remain. The interests of utility, safety, and esthetic appeal would thus all be served by the one treatment. But the measure suggested could be entirely unacceptable in a different environment or with a different tree species.

NOTICE: A uniform system of naming report series has been adopted for U. S. Forest Service Experiment Stations. Beginning January 1, 1963, research documents published by the Forest Service will be in one of these three series:

1. A numbered series, **U.S. Forest Service Research Papers.**
2. A numbered series, **U.S. Forest Service Research Notes.**
3. A numbered series, **U.S. Forest Service Resource Bulletins.**

The publishing unit will be identified by letters before the number, and the numbers will be consecutive in the order of publication dates. For example, this Station's first Research Paper in 1963 is designated U.S. Forest Service Research Paper PSW-P1.

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